OBSERVATIONAL STUDY OF THE SNOWFALL SYSTEM ASSOCIATED WITH A MESOSCALE LOW FORMED OVER THE SEA OF JAPAN

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1. INTRODUCTION

When cold air outbreaks occur from the Eurasian Continent, mesoscale lows frequently formed over the Sea of Japan, which are also referred to as "polar lows". A lot of mesoscale lows are associated with the JPCZ (Japan-Sea Polar-airmass Convergence Zone) (Asai, 1988). The JPCZ extends from the lee side of the mountains around the joint of the Korean Peninsula to the central coast of the Japan Islands, and is characterized by strong convergence, horizontal shear and an active convevtive cloud band.

Snowfall systems within mesoscale lows bring intense and a large amount of snowfall to the coastal region of the Japan Islands in its landing (e.g. Ninomiya and Hoshino 1990). Strong gusts are also caused by mesoscale lows (e.g. Ninomiya and Hoshino 1990; Yamagishi et al. 1992). But there were not many reports for distributions and structures of snowfall systems in mesoscale lows which bring the severe phenomena. The understanding of the detailed characteristics of snowfall systems is important to clarify precipitation and wind speed distributions in mesoscale lows and is significant for the comparison with the results of numerical simulations which resolve clouds.

A mesoscale low associated with the development of the cloud band along the JPCZ generated at 14 January 2001. The snowfall systems formed within the mesoscale low are investigated using the observation data to clarify the characteristics of snowfall systems in a mesoscale low.

2. DATA

The data obtained by the two C-band Doppler radars of Hokuriku Electric Power Company set at Goishigamine and Mikuni is used. The radar sites and observation ranges are showed in Fig. 1. The radar data was made into CAPPI (Constant Altitude Plan Position Indicator) data. Horizontal wind was derived from the two Doppler radar data.

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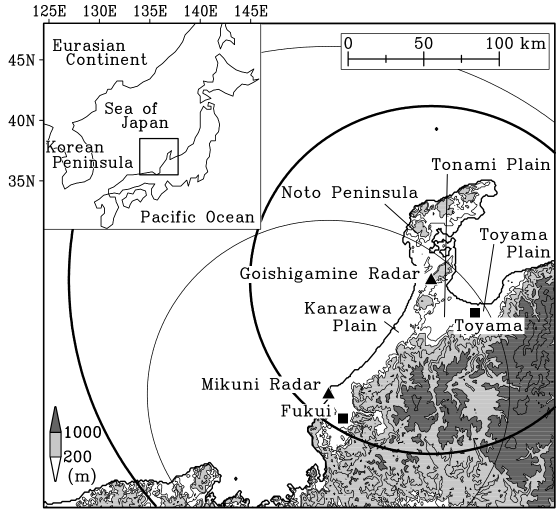

Fig. 1 Locations of observation points. The marks of ▲ indicate the observation points of the C-band Doppler radars of Hokuriku Electric Power Company set at Goishigamine and Mikuni. The small and large solid circles indicate observation ranges of radius of 120 and 240 km of the radars, respectively. The surface observation points at Fukui and Toyama are marked with ■. The altitude of topography is shown with contours (0, 100, 200, 500, 1000 and 2000 m) and gray levels (0, 200 and 1000 m).

The RANAL (Regional Objective Analysis), AMeDAS (Automated Meteorological Data Acquisition System) and surface observation data of the JMA (Japan Meteorological Agency) are also utilized. In addition, the GMS (Geostationary Meteorological Satellite) data received at Nagoya University is employed. The surface observation points (Fukui and Toyama) of the JMA are showed in Fig. 1.

3. FORMATION OF A MESOSCALE LOW ASSOCIATED WITH THE DEVELOPMENT OF THE CLOUD BAND ALONG THE JPCZ

The cloud band along the JPCZ have formed over the western part of the Sea of Japan by the afternoon of 14 January 2001. At 500 hPa, an upper-level synoptic-scale trough was located over the Chishima Islands. Over the Eurasian continent, an upper-level mesoscale

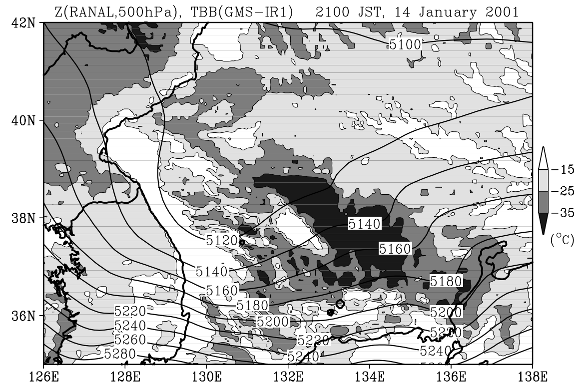

Fig. 2 Geopotential height (solid lines every 20 m) at 500 hPa of RANAL, and T_{BB} (gray levels; –35, –25 and –15 ℃) of the infrared imagery of the GMS at 21 JST, 14 January 2001.

trough (UMT) was present. The UMT progressed along the rim of the upper-level synoptic-scale trough and was located over the Sea of Japan in the afternoon of 14 January 2001. Satellite imagery showed that the southeastern part of the cloud band along the JPCZ rapidly developed from 15 JST (Japan Standard Time), 14 January when the UMT approached the cloud band. T_{BB} (equivalent black body temperature) was lower than –45 ℃ in the minimum. This indicates deep and active convection for a period of a cold air outbreak (Fig. 2).

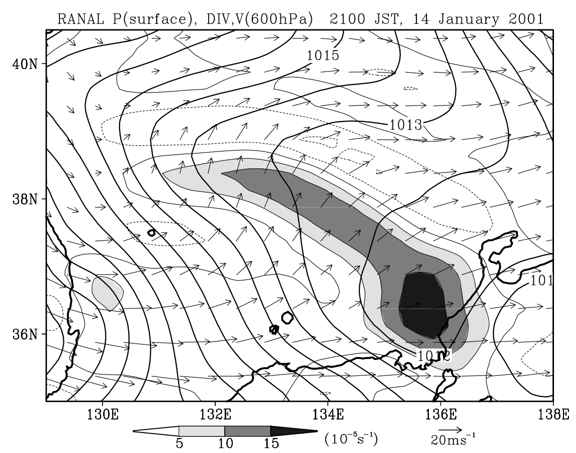

Fig. 3 Horizontal divergence (thin lines every 5×10^{-5} s^{-1} with gray levels than 5×10^{-5} s^{-1}), horizontal wind (arrows) at 600 hPa and the surface pressure (thick lines every 1 hPa) at 21 JST, 14 January 2001.

Weak wind zone with the southwesterly wind was present along the intensified cloud band from 700 hPa to 500 hPa. On the other hand, strong wind zone with the southwesterly wind was formed along the northeastern region than the weak wind zone. The weak and strong wind zones formed a divergence zone from 700 hPa to 500 hPa on the northeastern region than the cloud band. On the surface, a trough deepened below the upper-level divergence zone (Fig. 3). A mesoscale low formed in the deep surface trough.

4. EVOLUTION AND STRUCTURE OF SNOWFALL SYSTEM WITHIN THE MESOSCALE LOW

Radar echo showed that the snowfall system along the JPCZ moved toward NE when the cloud band developed. Southerly or easterly wind which blew toward the mesoscale low formed in the Kanazawa Plain, the Tonami Plain and the Toyama Plain. In the northern region than the cloud band (CB in Fig. 4 a) along the JPCZ, transeverse mode snowbands which extended from SW to NE intensified near the coastal region of the Kanazawa Plain and formed a intense and broad snowband with a width of 20 km (B1). B1 was confluent to the snowfall system along the JPCZ (CB) which moved toward NE. Another snowband (B2) also formed around the Tonami Plain and Toyama Plain between monsoon wind and offshore wind, and moved northward (Figs. 4a and b). Around the Kanazawa Plain, a snowband (B3) was formed from CB along the JPCZ. Some snowfall systems including B1, B2 and B3 gradually formed vortexlike echo pattern (Figs. 4b and c). In the southern region than B3, an echo free region was present (Fig. 4c). The echo free region corresponded to the cloud free region of the satellite imagery. This indicates that the echo free region was the descending current region. The vortexlike echo moved toward SE and its center landed around Fukui. In the rear (northwestern part) of the vortexlike echo, some snowbands along the wind direction and isolated echo group formed (Fig. 4d). These snow clouds were present in the region in which the cold air outbreak was intensified by the mesoscale low. The snowbands in the rear of the vortexlike echo were connected with the cloud band along the JPCZ. Then, the cloud band along the JPCZ moved southward and gradually became weak. The northward and southward movement of the cloud band along the JPCZ associated with approach of a UMT was reported in Nagata (1992).

Reflectivity and horizontal wind derived from the two Doppler radar data in the lower level are showed in Fig. 5 when the vortexlike echo was clear. The horizontal wind showed a clear vortexlike pattern. The wind velocity and direction rapidly changed along B3. The strong west-southwesterly wind region was present in the southern region than B3. The horizontal shear was about 30 m s^{-1} per a horizontal distance of 50 km.

Surface observation at Fukui showed that the temperature rose by about 2 degrees when B3 passed over Fukui around 23 JST, 14 (Fig. 6). At the same time, the wind speed became strong, and the wind direction changed from SE to SW.

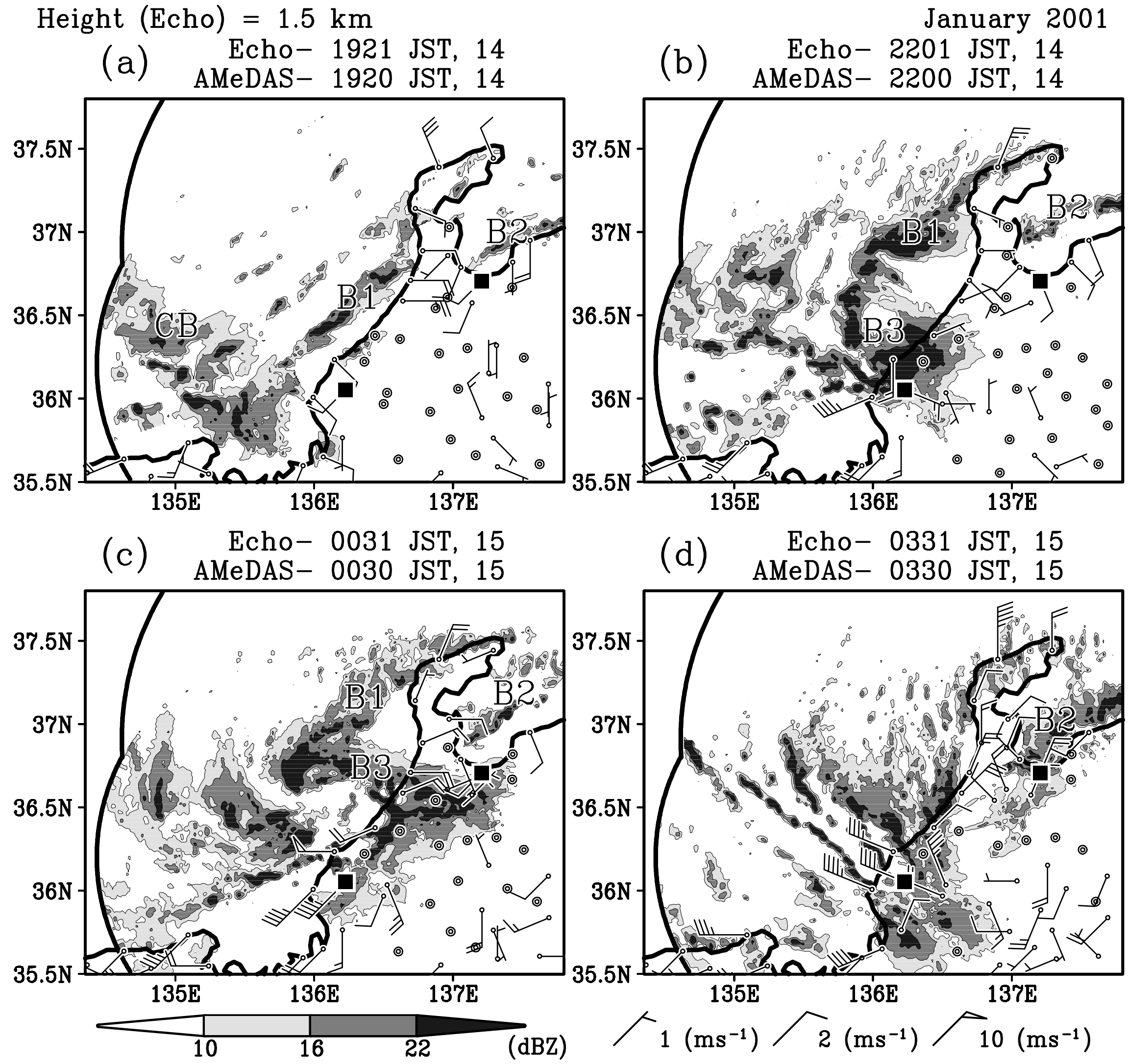

Fig. 4 Reflectivity (gray levels; 10, 16 and 22 dBZ) at a height of 1.5 km and horizontal wind (half barb; 1 m s^{-1}, full barb; 2 m s^{-1}, flag; 10 m s^{-1}) at the AMeDAS points at (a) 1921 (1920) JST, 14 (b) 2201 (2200) JST, 14, (c) 0031 (0030) JST, 15 and (d) 0331 (0330) JST, 15 January 2001. The surface observation points at Fukui and Toyama are marked with ■.

The instantaneous wind speed of 22.8 m s^{-1} were observed at 2350 JST, 14. When B3 moved northward after passing Fukui, the wind speed at Fukui gradually became weak.

The time series of meteorological elements at Toyama are presented in Fig. 7 .This indicates the changes which are accompanied by B2. The wind direction changed from NW to SW when the mesoscale low developed over the sea around 14 JST, 14. At the same time, the temperature decreased by about 1 degree. After that, B1 gradually formed from the transeverse mode snowbands. On the other hand, when B2 landed on the plain from the sea around 03 JST, 15, the wind direction changed northerly, and the temperature increased by about 1.5 degrees. This indicates that B2 was present in the zone with significant horizontal temperature gradient and shear, and relatively cold air was present in the southern region than B2. It is inferred that B1 formed on the same atmospheric condition as B2.

5. SUMMARY

When a upper-level mesoscale trough progressed over the Sea of Japan in the afternoon of 14 January 2001, the southeastern part of the cloud band along the JPCZ rapidly developed. The development of the cloud band was accompanied by the intensification of horizontal divergence from 700 hPa to 500 hPa. Below the upper-level divergence zone, a surface trough deepened. A mesoscale low developed within the deep surface trough.

The cloud band along the JPCZ developed and moved toward NE. A vortexlike echo pat-

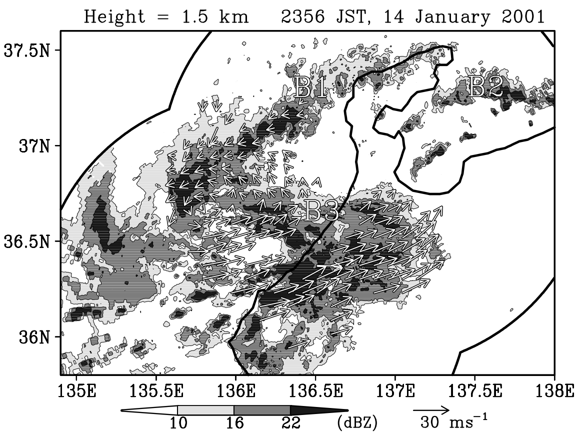

Fig. 5 Reflectivity (gray levels; 10, 16 and 22 dBZ) and horizontal wind (arrows) derived by the two Doppler radar data at a height of 1.5 km at 2356 JST, 14 January 2001.

tern gradually formed. The snowbands (B1, B2 and B3) within the mesoscale low formed in the shear lines which were accompanying the significant horizontal temperature gradient. In the region enclosed by B1, B2 and B3, relatively cold air was present, and southerly or easterly weak wind blew. The southern side than B3 was strong horizontal wind region with the instantaneous wind speed over 20 m s^{-1} and descending current. In the rear of the vortexlike echo which moved toward SE, some snowbands aligned along the wind direction and isolated echo group were present. Finally, the cloud band which were connected with the snowbands of the rear of the mesoscale low moved southward and became weak.

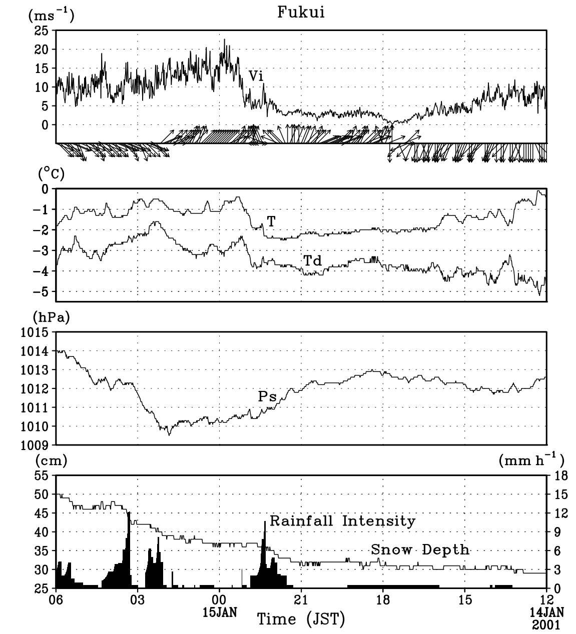

Fig. 6 Time series of the instantaneous wind (Vi), temperature (T), dew point temperature (Td), sea level pressure (Ps), rainfall intensity and snow depth at Fukui every 1 minute from 12 JST, 14 to 06 JST, 15 January 2001.

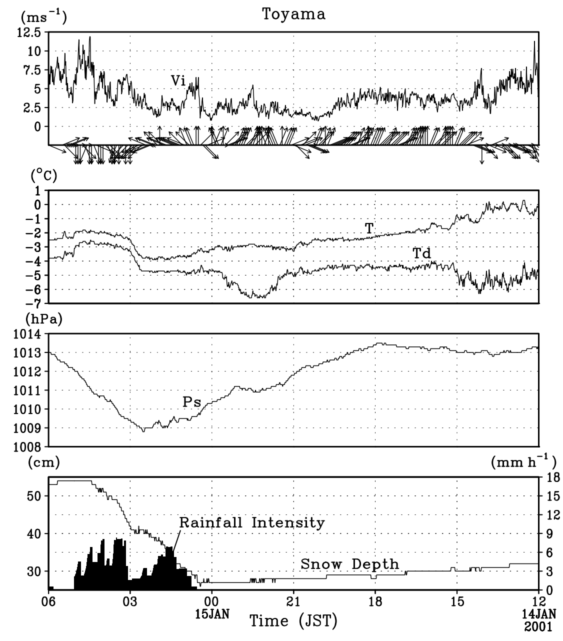

Fig. 7 As in Fig. 6 except for at Toyama.

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